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For

DETERMINATION OF TRANSMISSION BLOCKAGE IN AN OPTICAL TELECOMMUNICATION SYSTEM

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DETERMINATION OF TRANSMISSION BLOCKAGE IN AN OPTICAL TELECOMMUNICATION SYSTEM

FIELD OF THE INVENTION

[0001] The present invention relates generally to optical free space telecommunication systems and more particularly but not exclusively, relates to determining a blockage of an optical transmission in a network and optionally determining the nature of the blockage.

BACKGROUND

[0002] With the increasing popularity of wide area networks, such as the Internet and/or World Wide Web, and local area networks, users continue to demand faster access through the networks. Furthermore, an increasing load as well as complexity of information that is transmitted requires increased capacity for the network systems.

[0003] A solution to these needs is the use of optical free space telecommunications technology to transmit optical signals across wireless free space pathways. Such optical telecommunications utilize a beam of light as an optical communications signal with data encoded into the beam and then sent through a free space pathway from a transmitter to a remote receiver. Optical communication systems are capable of much higher data rates than traditional radio frequency (RF) systems. For example, point-to-point laser communications may use a narrow optical beam that has the potential for very large data gathering capacity and high directivity to efficiently focus the light onto the receiver. High directivity may result in greater security and lower probability of interception.

[0004] It is important for these free space optical communication systems to set parameters that ensure general safety. There are several designated classes for types of optical exposures and associated safety standards established by organizations, such as the American National Standards Institute, American National Standard for Safe Use of Lasers, ANSI Z136.1-2000 (2000), New York, NY, as enforced by Occupational Safety and Health Association (OSHA); the Food and Drug Administration (FDA), Center for Devices and Radiological Health (CDRH), Performance Standards For Light-Emitting Products, Code of Federal Regulations (CFR), Volume 21, Part 1040, Subpart 10, Subchapter J; and International Electrotechnical Commission (IEC) International Standard, Safety of Laser Products, Part 1, Equipment Classification Requirements and User's Guide, IEC 60825-1, Amendment 2 (2001-01) Geneva, Switzerland. The standards may suggest how to apply lasers, laser product requirements, such as power levels, maximum permissible exposure (MPE), etc. Power requirements may vary for optics that are exposed to an unaided eye versus aided eye, e.g. use of a magnifying device, such as binoculars or a telescope.

[0005] Another consideration in employing optical communication systems is the occurrence of a blockage in the pathway of the optical beam. Such interference may significantly or even totally reduce the amount, i.e. power, of light reaching the receiving end of the pathway. Another potentially resulting problem is a loss of accurate directivity where, for example, a tracking mechanism fails to maintain focus onto the intended point of reception.

[0006] The systems attempt to optimize the transport of the optical data during changes in conditions in the environment. Often it is preferable to increase or decrease

the power of an optical beam to comply with the safety guidelines. It is also preferable to project the light at a low level that also maintains adequate link margin in order to prolong equipment life. The nature of the blockage may profoundly affect the type of changes that the system may make in response to the blockage to provide safety measures and preserve link margin of the system. In addition, systems which attempt to sense blockages by use of detectors, must be able to distinguish between actual blockages of the pathway and other signals, such as variations of background light and light generated from other sources, such as other optical beams being projected in the network.

[0007] Prior optical communications systems fail to accurately detect blockages or provide sufficient information about a blockage in order to make appropriate changes in the system. In particular, currently available systems do not distinguish the nature of the blockage.

SUMMARY

[0008] The present invention provides a determination of a blockage present in a free space optical communication system that transmits an optical beam carrying data into a wireless pathway to a target receiver station in a network. Attenuation of the optical beam intended for receipt by a target receiver station is detected and compared with an attenuation of another optical beam intended for receipt by at least one reference receiver station in the network to determine a global blockage or local blockage of the pathway. The assignment of receiver stations as being target receiver stations or reference receiver stations can be dynamically varied, where any given receiver station that is intended to receive any optical beam of interest, is designated for the purpose of blockage assessment as a target receiver station.

[0009] Furthermore, at times, various system parameters may be changed based on the type of blockage. Where the blockage affects much or all of the area surrounding the pathway and network, it is considered global in character, such as conditions due to weather events. In some instances, it may be preferable for the system to increase the power of the optical beam to overcome the resulting attenuation from the global blockage. However, if the blockage is an obstruction that is significantly localized to the pathway, such as a person, it may be a local blockage. In this case, it may be desirable to decrease power or resist increasing power, so as to lessen the blockage's exposure to the beam. Moreover, if the source of the disruption is temporary, as is often the case with a local blockage, then an immediate and large increase in power in attempts to permeate the obstruction may result in sudden overexposure and saturation of the receiver if the blockage quickly departs. By contrast, a global blockage often gradually decreases the

beam's attenuation, so that an increase of power during the blockage is associated with less risk of saturating the receiver. After decreasing power due to a local blockage, the beam power may be incrementally increased or pulsed at increasing power amounts if no local blockage is found by repeatedly checking for the blockage, e.g. detecting attenuation and comparing the target and reference attenuation, until the power reaches a network based optimal amount.

[00010] In one embodiment of the communication system, backscatter is measured as an indication of a local or global blockage. In some instances, the optical beam may be transmitted by pulsing and only the backscatter during an extended period of time corresponding to backscatter from a global blockage is detected. In still further cases, backscatter may be distinguished from a local blockage and backscatter from the receiving station by the measured amount of backscatter from the intended beam with known transmitted power amounts from the transmitting and receiving stations. Modulation of the optical beam being transmitted may further distinguish between backscattering and other light, such as an optical beam projected from another station to the transmitter station.

[00011] The optical communication system often includes a network of multiple stations, including at least two reference receiver stations, and usually 5 to 50 reference receiver stations. In one embodiment, a reference receiver station is native, i.e. within, a transmitter station. Attenuation of another optical beam intended for this native reference receiver station may be detected prior to detecting the attenuation at the target receiver station. The network may also include a central station for sending instructions to the

transmitter station or receiver station to adjust a system parameter according to whether the blockage is local or global.

BRIEF DESCRIPTION OF THE DRAWINGS

[00012] The present invention is illustrated by way of example that is not intended for limitation, in the figures of the accompanying drawings, in which:

[00013] **Figures 1A** and **1B** are block diagrams of one embodiment of an optical telecommunications system, in accordance with the teachings presented herein, wherein in **Figure 1A** a local blockage is present and in **Figure 1B** a global blockage occurs.

[00014] **Figure 2** illustrates one embodiment of a transmitter station according to the present invention.

[00015] **Figures 3A, 3B** and **3C** illustrate various views of one embodiment of a receiver station, wherein **Figure 3A** is an external view of a receiver station and **Figure 3B** is an internal view of the receiver station of **Figure 3A**, and **Figure 3C** is an expanded internal view of a detecting end of the receiver station, in accordance with the teachings herein.

[00016] **Figure 4** illustrates one embodiment of an optical telecommunication system with a transmitter station having multiple native reference receiver stations, in accordance with the teachings herein.

[00017] **Figure 5** is a flow chart depicting one method for determining the nature of a blockage, according to the present invention.

[00018] **Figures 6A, 6B** and **6C** are graphs of some examples of backscatter received by a monitor with a voltage over a period of time, wherein **Figure 6A** represents the backscatter from a local blockage, **Figure 6B** represents backscatter from a global blockage, and **Figure 6C** represents backscatter from a modulated optical beam.

[00019] **Figure 7** illustrates one embodiment of backscatter from a local blockage interfering with an optical beam and backscatter from an optical beam reflecting from a receiver station, according to the present invention.

[00020] **Figures 8A, 8B, 8C** and **8D** show various embodiments of interconnected communications system having multiple reference receiver stations, wherein **Figures 8A** and **8C** represent examples of a local blockage and **Figure 8B** and **8D** represent a global blockage, according to the teachings presented herein.

[00021] **Figure 9** is a block diagram of a machine-readable medium storing executable code and/or other data to provide one or a combination of mechanisms to determine a blockage and its nature and adjust system parameters accordingly, in accordance with one embodiment of the present invention.

DETAILED DESCRIPTION

[00022] An optical communication system is provided having interconnected stations for communicating data. The system includes at least one transmitter station to convey data through a wireless pathway to a receiver station. An obstruction of the pathway is determined by measuring the attenuation of an optical beam arriving at a receiver station. The measurement may be further compared with the attenuation of other optical beam(s) arriving at one or more other receiving stations in the optical communication system. The received power amounts are interpreted to determine the nature of the blockage. The blockage character may be considered in controlling various parameters in the optical data transmission system, for example, by allowing high power operation during global blockage conditions to permit the system to operate with a greater margin without compromising safety as could result when a local blockage is present.

[00023] **Figures 1A** and **1B** illustrates one example of an optical communications system **2** in which a primary transmitter station **4** prepares optical beam(s) and conveys a primary optical beam **12** along a target pathway **10** to a target receiver station **6**. Furthermore, the optical communications system **2** includes at least one reference receiver station **8** to accept another optical beam **16** traveling down the length of a reference pathway **14**. The optical beam **16** directed to the reference receiver station is independent of the optical beam **12** intended for the target receiver station **6**. The reference receiver station **8** has the same or similar components as the target receiver station for accepting an optical beam **16** that is discrete from the primary optical beam **12** when released into a pathway. In one embodiment, the reference receiver station **8** is a site that is separate and remote from the target site within the network of the optical

communications system. In another embodiment, a reference receiver station **8** may be combined within the primary transmitter station.

[00024] As illustrated in **Figure 1A**, a local blockage **18** may occur to obstruct the target pathway **10** and inhibit some of or the entire optical beam from reaching the target receiver **6**. A local blockage may include an object, such as a person; an animal; a vehicle; any moveable item; or the like, that happens across a point along the pathway and causes attenuation of the received beam intended for the target receiver station. For example, where the communication system relays an optical beam at an elevated distance from the ground, the local blockage may be a window washer or other worker on a building ledge, a bird, a helicopter, a kite, fallen debris, etc. A local blockage may occur at a single pathway in the system network, or be localized within a small percentage of the pathways in the system, such as two or more pathways that are close to each other, e.g. parallel, intersecting or otherwise within a proximal area at the point of the local blockage.

[00025] In some instances as depicted in **Figure 1B**, a global blockage **20** may occur to cause at least partial attenuation of the optical beam **12** intended to reach the target receiver station **6** and the optical beam **16** to reach the reference receiver station **8**. A global blockage is an obstruction that is distributed across the pathways leading to at least one other, and usually many or all of the receiving stations in the optical communications system. Commonly, the global blockage includes impedances brought on by such as fog, snow, rain, haze, other weather conditions that involve particles in the air that cause absorption, scattering, scintillation, and the like. The global blockage may also include pollution, smog, smoke, etc.

[00026] Although **Figures 1A** and **1B** demonstrate one layout of an optical communications system, the scope of the present invention anticipates that the optical communications system may communicate with any number of reference receivers, e.g. 1 or 2 to 100, and transmitters arranged in various fashions within the communications system. Furthermore, the transmitter station(s) and/or receiver station(s) may also be transceivers, i.e. functional to both transmit optical beams and receive optical beams. Usually, a local blockage occurs at a single pathway to a target receiver, and only a second pathway to a reference receiver need be assessed to determine the nature of the blockage. In another embodiment, a local blockage occurs at two pathways in the system and attenuation values at a third or multiple reference receivers are used to determine the nature of the blockage.

[00027] The optical beam **12** transported through the optical communication system may have data system management information, e.g. status information and control signals, and/or other information, modulated thereon. The optical beam may be monochromatic or any wavelength or color, and may include visible light as well as ultraviolet or infrared portions of the spectrum. In one embodiment, the optical beam has a wavelength of about 1500-1600 nm, e.g. about 1550 nm, and a transmit divergence of about 0.8 mrads (milli radians).

[00028] As shown in **Figure 2**, the transmitter station **4** may have an optical generator **30** to create an optical beam that carries data and a releasing end **56** that has components to shape and send the beam into a pathway. The generator may include a data source **32** for supplying digital data to a light source **34** to be integrated into an optical beam. The data is any information that a user may desire to be transferred to a receiver. The optical

beam may incorporate the data through any of several conventional techniques, such as on/off keying, for example, in which a "one" may be indicated by the light on and a "zero" by the light off, or vice-versa. Other techniques include phase encoding and frequency encoding. A modulator **54** may be used to affect the electrical signal of the optical beam. For example, the modulator may be used to superimpose a modulation onto the signal from data source **32** to partially or substantially fluctuate the power of the optical beam to facilitate phase, frequency, or amplitude encoding. Furthermore, a modulator, such as a mechanical chopper or an electro-optical modulator, may also be included after light source **34** to fluctuate the wave front, polarization, phase, amplitude, or the like, of the beam and assist in encoding.

[00029] The light source **34**, e.g. a laser, generates an optical beam that is usually a modulated and encrypted, high-speed (10 Mpbs- 10 Gbps) optical beam. A laser as the light source, such as a suitable commercially available distributed feedback (DFB), may be powered by an electronic drive signal.

[00030] The optical generator **30** portion of the transmission source may also optionally include an amplifier **36** to increase power of the optical beam **44**. One exemplary amplifier is an erbium doped fiber amplifier (EDFA).

[00031] The releasing end **56** is in communication with the optical generator **30** to further prepare the beam for sending into a pathway. The releasing end often includes beam-shaping unit **38**, such as a telescope, that may be coupled to the optical generator to form the appropriate wave front of the optical beam to optimize the transfer and receipt of the optical beam by the receiving station. In some cases, the beam shaping unit may make the optical beam nearly collimated and with a small angle of divergence. For

example, the beam may have .8 mrad divergence after leaving the shaping unit. The beam-shaping unit often includes at least one lens, mirror or diffractive optical element **40** for shaping the beam. There may also be a filter, e.g. an adjustable filter wheel, located within or after the shaping unit and prior to the exit of the transmitter station. In some embodiments, a beam splitter is present to divide the beam prior to sending. Also connected to or after the beam-shaping unit **40** is a transmitter aperture **42** through which the optical beam **44** released into the pathway.

[00032] The light may travel within the transmitter station to the components of the transmitter station through a variety of transport mechanisms. For example, the light may move from the light source and to the amplifier and/or beam shaping unit through a fiber **46** running between the components, through free space or with the assistance of mirrors to direct the movement, etc. The components may be also coupled in various orders in addition to the arrangement shown in the figure. Furthermore, in one embodiment, all or some of the components of the optical generator are not disposed within the transmitter station, but are located external to the transmitter station and the light or data signals travel into the transmitter station.

[00033] The transmitter station may also have other optional components to assist in producing or processing an optical beam, for acquiring and analyzing control signals, reference data, backscattering, background light, etc. Furthermore, the transmitter station may include the components of a receiver station for receiving an optical beam from another transmitter station, or other components. For example, in one embodiment, the transmitter station also has a power controller **48** for increasing or decreasing the power of the optical beam released into the pathway. The power controller may respond to a

finding of a particular type of blockage in the pathway. The power controller **48** may include or affect the light source **34**, the amplifier **36**, a filter, e.g. a filter wheel, or other mechanism for manipulating the amount of optical beam power.

[00034] In addition to the transmission of optical beams, the transmitter station is often in communication with the receiver stations, other transmitter stations and/or a central station in the communication network at the communication interface **52**. The communication interface **52** may use any of a variety of communication schemes to accept system management information, such as the status of a station; attenuation at various receiver stations, e.g. target and reference receiver stations; backscatter detection; parameter control instructions, e.g. directions to adjust power of an optical beam, filter strengths, etc. These communication schemes may include electrical wire links, e.g. T1 connection, use of radio frequency or optical frequency from a communication source employing any of the numerous communication standards used in the telecommunication industry. For example, communication may be through a network, e.g. an Internet connection, satellite transmission, Ethernet connection and other communication links for transferring information or control instructions to and/or from any of the stations in the optical communications system. Furthermore, transmission of status and control information may be made through encoded into an optical beam with in-band system management information integrated into the band received by the transmitter station, e.g. through the communication interface or other detector.

[00035] Furthermore, the transmitter station may include a monitor **50** to detect backscattering of the optical beam. Typically, the detected backscatter amount will be normalized by the transmitted power amount from the transmitter station so that the

processed backscatter signal is independent of the transmitted power amount. The monitor may also be used for evaluating a sample of the optical beam, such as beam shape, power, etc. One such monitor utilizes a lock-in amplifier following the optical-to-electrical signal detection, that applies phase sensitive detection to filter out noise, i.e. improve signal to noise ratio, and increase phase sensitivity of the optical power detected. A lock-in amplifier uses the process of synchronous (or phase sensitive) detection to recover signals that have been buried in noise. The component acts as an extremely narrow pass band filter with the center point of the pass band selected by a reference signal.

[00036] Another optional component is a tracking unit, such as a quad detector or device having an array of sensors, e.g. camera-based sensor, which assists in tracking of the optical beam to the receiver station's aperture. In the quad detector embodiment, the detector is sectored into four equal portions and a portion of the optical beam from the receiver station is made to hit the center of the quad detector which coincides with the shared vertex of the four sections. If the beam hits outside of the center point, the tracking is off and may be adjusted. In some embodiments, the tracking unit, e.g. quad detector, also serves as the monitor **50** to detect and determine backscatter.

[00037] Various components may also be present in the transmitter station to direct the beam to various other components. The transmitter station may contain beam splitters to direct a portion of the beam to another transmitter station component, such as a tracking unit or monitor. In addition, mirrors may be provided to direct the beam to certain components.

[00038] **Figure 2** demonstrates one embodiment of a transmitter station, the scope of the present invention anticipates that in other embodiments, transmitter components may be arranged in various fashions within the transmitter station or outside of the transmitter station and coupled to the transmitter via fiber links or other communication mechanisms. For example, modulator **54** may be in the optical generator in a position prior to or after the light source **34**. Furthermore, the optical generator may be external to the transmitter station and be coupled to the transmitter by a fiber, which transports the light to the transmitter.

[00039] In general, the target receiver station has light gathering and filtering elements and at least one optical detector and may include a tracking device, demultiplexing components and decoding circuitry. In addition, the reference receiver station has all or most of the same components as the target receiver station. **Figures 3A**, **3B** and **3C** show various views of a receiving station **6** that also includes transmitter components **52** as described above for the transmitter station **4** and a fiber **46** extending from the transmitter components **52**.

[00040] **Figure 3A** shows the external view of a receiver station that includes a receiver aperture **70** for collecting the optical beam from the pathway. A transmitter aperture **42** may also be present where the receiving station also sends optical beams. As shown by the internal view of the receiving station **6** in **Figure 3B**, the optical beam **44** enters through the receiving aperture **70** and reflects off of a series of mirrors, e.g. primary mirror **72** and secondary mirror **74**. The mirrors direct the optical beam **44** to the detecting end **80** of the receiving station for detection.

[00041] **Figure 3C** shows one embodiment of the detecting end **80** having a receiving point **82** for entry of the optical beam **44.** A steering mirror **84** reflects that optical beam onto a focusing lens **86.** The focusing lens passes the light beam to a fold mirror **88.** The light beam may optionally continue to a beam splitter **90,** which splits a portion of the optical beam to a detector **92** for measurement and a portion of the optical beam to a monitor **50** which may also function as a tracking sensor. Usually the detector may sense light in the nano watts level or smaller, such as pico watts amounts. The monitor **50** is an optional component for evaluating a sample of the optical beam, such as beam shape, amount of power, backscattering detection, etc. The monitor is especially useful where the transmitter station incorporates the components of the receiving station.

[00042] In addition, various other components may be provided in a receiver station and/or transmitter station, such as one or more lenses, filters, mirrors or beam splitters. **Figure 4** shows one variation of a split beam transmitter station **100** for sending multiple optical beams **112, 122, 132** created by at least one optical generator **102** into discrete pathways **110, 120, 130,** respectively. The transmitter station has an optical generator **102** component and fiber **105** leading to multiple releasing ends, e.g. a primary releasing end **106** to send the primary optical beam **112** in pathway **110** to target receiving station **108,** and other releasing ends **138.** Each releasing end may have a beam shaper unit and has a transmitter aperture (not shown), which sends an optical beam to a reference receiver **140.** A beam splitter **104** divides the light into the appropriate number of beams for each releasing end. Individual reference receiver stations **118, 128** may also be associated with each releasing end of the transmitter station **100** as a component of the transmitter station or as a receiver station that is external (not shown) to the transmitter station. The native

receiving stations **118, 128** of the transmitter station **100** accept optical beams **116, 126, 136** along pathways **114, 124, 134,** respectively from transmitters **142.**

[00043] To determine a blockage for this particular embodiment of split beam transmitter station having numerous receiver stations, a primary optical beam **112** may be transmitted from primary releasing end **106** into pathway **110.** The transmitter station may examine native associated receiver station **118** that is associated with the primary releasing end **106** for any attenuation above acceptable or normal limits. Where an above threshold attenuation is found either in the native associated reference receiver station **118** or in target receiver station **108,** the transmitter station may determine that a blockage is present. Consequently, the transmitter station may opt to poll one or more other native reference receiver stations **128** within the transmitter station or remote reference receiver stations **140** distant from the transmitter station, in order to determine the nature of the blockage and the appropriate change of system parameter action relative to the pathways affected by the blockage. The transmitter station may also opt to poll other transmitter stations in the network.

[00044] As shown in the flow diagram of **Figure 5**, one method of determining blockage is by measuring attenuation of the optical beam arriving at the target receiver station at a period of time **152.** The attenuation is compared to a regular value of attenuation for that target receiver station **154.** The regular value may be the average amount of attenuation for a given period, the typical amount of attenuation determined to occur in a particular day of the year and time of day, or other convenient standards based on predicted power received without the blockage. The regular value is measured by characterizing the link and taking into account daily common sources of link loss, such as

windows, range loss, fiber loss, etc. If the result of the comparison with the regular value determines an unacceptable measured attenuation, which may be a range of amounts or any amount, a blockage is indicated **156**. If there is no blockage, the normal operations continue **172** and the procedure ends **174**. At any time the procedure may begin again. Often the procedure reiterates on a regular, prescheduled basis, such as every second.

[00045] Where a blockage is indicated, the system may opt to query reference receiver(s) to determine the type of blockage and possibly make corrective changes in parameters. For the same time period that is being studied regarding the target receiver, the attenuation of another optical beam of at least one reference receiver station is measured **158**. The resulting value for each receiver station is compared to a regular value for that receiver station to determine a variation attenuation value for the period of time **160**. If the variation attenuation value is greater than a pre-defined tolerable amount, e.g. over 4 dB, over 10 dB, over 50 db, or other amounts, then a blockage is suggested at that site **162**.

[00046] In other embodiments, where more than one reference receiver station is used, the average variation attenuation value may be determined and compared to attenuation at the target receiver. This averaging process may factor in the distance that a reference receiver is located relative to the target reference receiver, power levels, and other factors. For example, the value of a closer reference receiver station may be caused to have greater impact on the average than the value from more remote reference receiver stations.

[00047] In a further alternative embodiment, the variation attenuation value of the reference receiver station(s) **160** is compared to the variation attenuation amount of the

target reference **154** to result in an interference value that is caused by a blockage. This interference value specifies whether the attenuation at the reference receivers is similar or the same as the attenuation at the target receiver, thereby indicating a global blockage, or sufficiently different to suggest a local blockage. This comparison may factor in any difference in power levels of the transmitted optical beams and difference of reference pathway length(s) and target pathway length, and the like. A range of tolerable variances may also be considered in the comparison process to account for microclimate effects and other causes of error.

[00048] If there is a blockage at that reference receiver station, then a global blockage is suggested **164**. Otherwise, a local blockage may be interpreted to be present **166**. At this point, the system may decide that a system parameter should be altered. The decision to change a parameter may be based, *inter alia,* on many aspects of the communication system, classes for optical beams and their safety regulations, goals for the transmission, etc.

[00049] The communication system may respond to a particular type of blockage by authorizing the adjustment of certain system parameters that may affect the primary transmitter station, target receiver and/or any of the reference receivers. For example, a global blockage may cause the system to increase the power amount of the optical beam by increasing the power of the light in forming the optical beam at the transmitter station, decreasing filtering or attenuation at the transmitter station or by decreasing the filtering or attenuation amount at the receiver station. In the alternative, a decision may be made to maintain power amounts where a global blockage is determined. The decision to increase the power of the optical beam may be based on the sensitivity of the system. In

some systems, the link performance is maintained even with a significant percentage of the beam being blocked. For example, a link may be continue to be available even if over 90% of the beam is blocked and resulting in a 10 dB reduction in link margin. For a local blockage, the system may opt to decrease the amount of power in the optical beam, such as for safety considerations, by decreasing power at the transmitter station **100**. In the alternative, a decision may be made to maintain power amounts where a local blockage is determined. In addition, where the attenuation is decidedly caused by a blockage, the transmitter station and/or receiving station may not vary the tracking system to better align the focus of the optical beam onto the receiving aperture when the blockage is removed.

[00050] However, an operation parameter change may not accompany every indication of a particular type of blockage. For example, a local blockage may be detected, but where the current optical beam is within allowable levels for the blockage, a decision to maintain steady power amounts may be made.

[00051] The system may decide that it has sufficient information regarding the blockage type and scope. The process may simply end **174**. In some cases, where an operation parameter was changed, the system may return to normal operations **172** prior to ending **174**.

[00052] In order to make a more accurate determination of the blockage type, the system may opt to poll other receiver stations **170**. For example, where a global blockage is possible, the system may want to ensure that no local blockage is present prior to opting to increase power. The process of measuring **158** and comparing values **160** for another reference receiver is repeated, until the system chooses not to continue polling,

for example, if it is determined that there is no longer a blockage present or a global blockage is insignificant enough to ignore. The power may return to or remain at normal **172**, e.g. optimal or default levels for the system and the process ends **174**.

[00053] The system may be configured to test whether the blockage is gone and it is safe to return to normal or different operations. In one embodiment, after the optical beam power is decreased due to a local blockage, the transmitter station increases the power of the beam by small increments or sends quick pulses of increased power, such as to avoid exceeding safe exposure limits, and repeats the detecting of attenuation and comparing the attenuation to reference receiver(s) with each power increment or pulse level. If no local blockage is found, the power increase and check for blockage may be reiterated until the optical beam is at an optimal power amount for the system. This optimal amount of power depends on various factors that influence the receipt of the optical beam, such as distance, sensitivity of the receiving detector, established standards for optical communications, and weather conditions, etc. For example a low optimal power amount may be preferred for a clear day

[00054] In one embodiment, the target receiver selects portions of the received optical data stream for output to a user optical transceiver interface output, which in turn, may be connected via a high-speed networking connection to user equipment, which may include data routing circuits. The data routing circuits direct the data to node addresses, via free space optical backbone network-to-network links or anywhere on other networks connected to the routing circuitry.

[00055] When the optical beam hits a blockage or other scattering sources, often the light is scattered in various directions including back toward the transmitter station. The

transmitter station may detect such backscattering to also distinguish between typical local, a fixed source, i.e. that is not temporarily present, global blockages, other distributed scattering sources along the path to the receiving station and scattering from a receiving station. The transmitter station may have an external monitor capability, such as a transmissometer, or other such device to measure the amount of light extinction over the length of the distance from the blockage scattered back to the transmitter station.

[00056] In one embodiment, the optical beam conveyed from the transmitter station may be pulsed at a convenient rate and the backscatter intercepted by the monitor. As the pulsed beam contacts a local blockage, the backscatter will hit the monitor at a particular time, depending on distance from the transmitter station that the local blockage is located, the type of local blockage, e.g. the reflective surface of the blockage, the power of the optical beam, etc. Often, the local blockage is near to the transmitter station and the backscattering enters the monitor very soon after it is transmitted, e.g. 10 nsec. The pulsing permits the monitor to track the distance that a blockage is located according to the time in which the backscatter is collected relative to the time that it is transmitted into the pathway.

[00057] In addition, a local blockage typically consumes only a small and defined portion of the pathway. By contrast, a global blockage or other distributed scattering source along the path usually invades much or the entire length of the pathway. The monitor may further be timed to open and accept only backscattered light from a pre-determined point from the blockage. The transmissometer may be gauged to be open during the time range when a blockage may be present along the far end of the pathway and through a large span of the pathway. The monitor gate may be closed for round trip

transit times that correspond to the distance within which a particular local near blockage or attenuator, such as a building window, often occurs. Thus, if the monitor detects backscatter during the open periods, a global blockage or other distributed scattering source is assumed. In addition, if the backscatter is detected over an extended period of time, then a fixed scattering source is determined to be present, rather than a source that may be removed, such as a person. This manner of measuring distance to a local blockage may be considered along with a known beam divergence amount and maximum permissible irradiance exposure conditions to determine a safe optical power level. Where a fixed source is determined, it may be decided that present conditions should be maintained, because a power sensitive blockage, such as a person or animal is not likely to be present.

[00058] Moreover, this timed monitoring embodiment may be employed to differentiate between fixed sources of attenuation, such as a window, and temporary sources, such as weather and a person, by measuring the backscatter. A fixed attenuation source results in a consistent backscatter pattern, i.e. measured amount of backscatter, at the same point along the pathway. An open gate monitor may indicate a nearby fixed source by the monitor accepting backscatter from only nearby or alternatively far away sources. The information regarding a fixed or temporary source may be further useful in deciding what, if any, changes should be made to system parameters. For example, it may be preferable to increase optical beam power where a fixed attenuation source is present but maintain or decrease power if a temporary source is detected.

[00059] **Figures 6A** and **6B** are graphs of an example of backscatter received by a monitor with a voltage over a period of time. In **Figure 6A**, a local blockage creates a

quick backscatter over time period T2 and occurs at a time T1 after the launch time T0 for sending the pulse. The monitor may be closed during the time T0 to the end of T2. As shown in **Figure 6B**, backscatter detected by a monitor caused by a global blockage occurs at a time T3 and continues for a prolonged time period T4, representing the depth of the global blockage. The monitor may be opened for all or most of the time period T4, and usually is opened after T2.

[00060] In still other embodiments as shown in **Figure 7**, the transmitter station **200** may distinguish between backscatter from a blockage **202** and backscatter that may arise from the optical beam **210** leaving a transmitter aperture **214** and reflecting from the exterior **206** of the receiver station **204**, such as the receiving aperture of the detector **208** or other surface. The monitor **216** determines the power of the backscattering, which is inversely proportional to the square of the distance of the blockage. Therefore, the amplitude of backscattering from a receiver station is much less than backscattering caused by a closer local blockage. Where the transmit signal is encoded with a reference modulator **54**, the monitor may utilize a lock-in amplifier following the optical-to-electrical detection to achieve high sensitivity.

[00061] In some optical communication systems, the target receiver station **204** sends an optical beam **212** to the transmitter station along the same or different pathway down which the optical beam from the transmitter station travels. In this case, the transmitter station monitor **216** may distinguish between the optical beam received from the receiver station and backscatter from a blockage. A modulator **54** may create cyclic partial modulations in the power of the outgoing optical beam. This partial modulation for distinguishing between backscatter and other light is in addition to modulation of the

optical beam used for carrying data or other information. The monitor is programmed to only detect the modulated backscatter that is matched to the transmitter station modulation signal rather than an optical beam from the receiving station or other stray light. In one embodiment, an optical beam from the receiving station directed to or happening to find the transmitter station is not modulated. In another embodiment, an optical beam from the receiving station has a substantially different modulation signal than the outgoing optical beam from the transmitter station. The use of a lock-in amplifier based sensor or other matched-filter receiver may have adequate dynamic range on the input and sufficient frequency isolation to avoid a false backscatter reading.

[00062] **Figure 6C** depicts a graph of modulation cycles for an optical beam with voltage that fluctuates over a period of time. The monitor detects an envelope **250**, i.e. one modulation cycle. For example, where detection is at 20 KHz modulation, then time for an envelope is the inverse of modulation, or 1/20 msec, i.e. 50 sec. A typical signal equals a modulation constant multiplied by the power of the backscatter plus background. Through the modulation procedure the background is ignored and only the power times the modulation constant is considered.

[00063] In still other alternative embodiments of an optics communications system, a beacon light, such as visible light, e.g. 550 nm, is projected by either the receiver station(s) or transmitter station. The opposing station includes a camera to view the pathway and detect the beacon light. The image captured by the camera is evaluated for determining whether a blockage is present and the type of blockage. For example, the present of fog may result in a hazy image of the beacon light.

[00064] As shown in one embodiment of a multiple-station, interconnected communications system in **Figures 8A** and **8B**, various stations, i.e. transmitter station **4,** target receiver station **6** and/or reference receiver(s) **8,** may serve as transceiver nodes to both send an optical beam and accept an optical beam from the target receiver or any of the reference receivers. For example, the transmitter station **4** may send optical beam **12** and accept other optical beams **16**. The target receiver **6** may also accept an optical beam from other reference receivers (transceivers) or transmitters in addition to or in place of receiving signals from transmitter station **4.** In **Figure 8A**, a local blockage **18** is present and in **Figure 8B** a global blockage is present.

[00065] The primary transmitter station may include reference components, which may serve as a reference receiver to accept an optical beam from the target receiver and/or reference receiver(s). In operation of this embodiment, the primary transmitter station may consider the attenuation information from the primary transmitter's own reference receiver for an incoming optical beam to determine a blockage and the nature of such a blockage. For example, the primary transmitter station may first detect attenuation at its native reference receiver of an optical beam released from the target receiver station. Upon detecting attenuation, the primary transmitter station may query the target receiver station to determine if attenuation is also present at the target receiver. If such attenuation is determined, then a blockage is determined to be present. To assess the type of blockage, the primary transmitter station may opt to poll for attenuation at one or multiple other reference receiver stations in the communication system network. In addition, the primary transmitter station may alternatively poll for attenuation at one of

multiple other transmitter stations or transmitter/receiver pairs in the communication system network.

[00066] The communications system may also optionally have a central station **22** to monitor the transmitter station(s) and various receivers. It is further intended that the user transaction system may include any number of central stations, including no central stations **22**.

[00067] The central station **22** may communicate with the receivers and transmitter station through various network communication schemes. In one embodiment, the link may be a T1 connection. The central station may gather data regarding the transmission and attenuation at the various receivers/transmitter stations. The central station may use this data to determine a proper course of action for the stations and direct the stations to behave accordingly.

[00068] In one embodiment, the central station also normalizes visible light readings obtained in the general network location or close by, with the optical beam data to be used as reference data in determining the nature of a blockage. For example, transmission of visible light, e.g. at about 532 nm (green visible light spectrum), such as the readings often acquired by airports, may be translated to the wavelength and characteristics of the optical beam, including the altitude of the beam compared to the visible light readings, and environmental factors between sites, such as temperature, humidity, wind speed, particulate levels, air pollution, etc. The optical transmission may be compared to the visible light readings for the same time period to determine a global blockage. In addition, weather patterns may be predicted by using past visible light data for a

particular time as a factor in determining a future or present occurrence of a global blockage.

[00069] **Figures 8C** and **8D** show another embodiment of a multiple-station, interconnected communications system in which transmitter/receiver pairs **324**, **328**, **330** and **332** are located within a sub-network **21**, such as a local area network (LAN) for a business, school, organization, etc., e.g. within a building, campus, etc., having a central station **322**. The resident nodes, i.e. transmitter/receiver stations, of the sub-network **21** are in communication with the central station through an Ethernet link or other convenient short distance communication scheme.

[00070] During operation, the central station **322**, may receive attenuation information from the resident primary transmitter/receiver pair **324**. The central station **322** may then opt to sequentially poll one or more of the resident reference receiver/transmitter pairs **328**, **330** and **332** that are within the sub-network. The central station **322** may also choose to poll the remote target receiver/transmitter pair **326** and/or the remote reference receivers **334**, i.e. on the receiving end of the transmitters within the sub-network, especially where further information is needed to make a system parameter decision. For example, if there is a blockage indicated at the primary transmitter/receiver pair but none of the resident reference receiver stations show attenuation amounts that indicate a global blockage, the central station may poll the remote target receiver and possibly the remote reference receivers to determine if a local blockage is present. **Figure 8C** depicts the presence of a local blockage **16** and **Figure 8D** illustrates a global blockage.

[00071] Various software components, e.g. applications programs, may be provided within or in communication with an optical communication system device such as the

central station, transmitter station and/or receiving station that cause the device to execute the numerous methods employed for determining the nature of a blockage and adjust system parameters in response to the determining, including sending instructions for such parameter adjustment. An optical communication system, e.g. a processor, executes the computer-readable medium, which may be locally or remotely located relative to the processor. **Figure 9** is a block diagram of a computer readable, i.e. machine-readable, medium storing executable code and/or other data to provide one or a combination of mechanisms to transmit and analyze light, according to one embodiment of the invention. The machine-readable storage medium **400** represents one or a combination of various types of media/devices for storing machine-readable data, which may include machine-executable code or routines. As such, the machine-readable storage medium **400** could include, but is not limited to one or a combination of a magnetic storage space, magneto-optical storage, tape, optical storage, dynamic random access memory, static RAM, flash memory, etc. Various subroutines may also be provided. These subroutines may be parts of main routines or added as plug-ins or Active X controls.

[00072] The machine readable storage medium **400** is shown having a determining blockage routine **402**, which, when executed, detects a blockage through measuring attenuation of a received optical beam by a detect blockage attenuation subroutine **404**. Thee program further compares attenuation at the target receiver with attenuation at one or more reference receiver stations through a compare subroutine **406**, as described above with reference to the method flow chart in **Figure 5**.

[00073] The medium **400** may also optionally have a backscatter routine **410** used to determine the nature of a blockage by detecting and analyzing backscatter of an optical

beam through implementing any of several subroutines. The measure backscatter subroutine **412** may be executed to quantify an amount of received backscatter and a compare backscatter subroutine **414** may interpret the backscatter amount to standards for a local blockage and/or a global blockage to determine the nature of the blockage. The routine and subroutines for backscatter monitoring is described above with reference to **Figures 6A** to **6C**.

[00074] In addition, the medium may also include an adjust parameter routine **420**, which may be executed through a variety of optional subroutines to vary the system parameters as triggered by the determination of a particular type of blockage as determined by the other routines. An increase power subroutine **422** allows the optical beam to be released with greater power or collected having greater power, e.g. decrease filtering or attenuation at the transmitter station or target receiver station, especially where the blockage is established to be global in nature. The decrease power subroutine **424** permits the optical beam to be released with less power, especially when the blockage is interpreted to be local. In some embodiments, a maintain tracking subroutine **426** is provided to restrict movement or refocusing of a transmitter station or receiving station where disruption is due to a blockage event. Such adjusting procedures are described above with regards to **Figure 5**.

[00075] In addition, other software components may be included, such as an operating system **430**.

[00076] The software components may be provided as a series of computer readable instructions that may be embodied as data signals in a carrier wave. When the instructions are executed, they cause an optical communication system device, e.g. a

transmitter station, receiver station and/or central station, to perform the blockage determining and adjusting steps as described. Such instructions may be presented to the processor by various mechanisms, such as a plug-in, ActiveX control, through use of an applications service provided or a network, etc.

[00077] The present invention has been described above in varied detail by reference to particular embodiments and figures. However, these specifics should not be construed as limitations on the scope of the invention, but merely as illustrations of some of the presently preferred embodiments. It is to be further understood that other modifications or substitutions may be made to the described user transaction system as well as methods of its use without departing from the broad scope of the invention. Therefore, the following claims and their legal equivalents should determine the scope of the invention.